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Type of a New Family of Mailed-Cheek Fish from the Japan Sea, *Marukawichthys ambulator*, n. g. n. sp.[1]

Kiyomatsu SAKAMOTO

(Received January 21, 1931).

A collection of fishes made in June to September, 1919, by the staff of the Toyama Fisheries Experimental Station in Toyama Bay includes a species which proved to be new to science. Its characteristics, however, demand not only a new genus but also a distinct family for it. It is with great pleasure the present author wishes to dedicate it to Mr. H. Marukawa of the Imperial Fisheries Experimental Station who kindly put the collection at his disposal. His warmest gratitude is also due to Professor A. Terao under whose direction the present study was carried out.

MARUKAWICHTHIDÆ, n. fam.

Body moderately elongate, tapering into a slender tail. Head large. Eye large, and placed high; the interorbital space narrow, and flattened; a bony stay connecting the suborbital with preopercle, covered by the rough skin; preopercle with about 5 sharp spines. Mouth horizotal; teeth equal forming villiform bands on jaws, vomer, and palatines; premaxillary protracticle; maxillary without supplemental bone. Gills $4\frac{1}{2}$, no slit behind last gill-arch; gill-rakers short, club-shaped; gill-membranes broadly united, free from the isthmus. Body covered with velvety prickles, without scale. Dorsal fins separate, the spines about 10, the soft dorsal elongate, caudal fin truncate; anal fin similar to the soft dorsal, without spines; pectoral large, with four free rays below, similar to those of Ereuniidae. Ventrals present, thoracic, the rays usually I, 4. Pseudobranchiae present. Lateral line distinct, armed

(1) Contributions from the Zoological Laboratory, Imperial Fisheries Institute, No. 18. (Nos. 16–17: A. Terao, Change of vitality with age as based on the living unit of organisms, I–II. Proc. Imp. Acad. **7** (1–2), 1931.)

with spines. Sides of the body with several series of curved spines. Pyloric coeca usually in small number (about 4); air bladder wanting.

This family is very close to Ereuniidae, but differs from it in having ventrals and without slit behind the last gill-arch. Type genus: *Marukawichthys*.

Marukawichthys, n. g.

Body moderately elongate and tapering into a slender tail, the nuchal region elevated. Head large, not compressed or depressed. Eye very large, and higher than the upper profile of head. Preorbital broad. Mouth horizontal, not large, lower jaw included, maxillary not extending to the anterior margin of the eye-ball. Teeth in villiform bands on jaws, vomer and palatines. Gill-openings very wide, gill membranes broadly united, free from the isthmus. Gills $4\frac{1}{5}$, no slit behind last gill arch; gill rakers short; club-shaped. Suborbital stay distinct, covered by the rough skin. Nasal spines present; two stout spines before eye; a much larger one on upper rim of orbit which gives off three small branches; a divided spine at nape; two moderate spines near the upper margin of opercle; a strong one on the upper portion of base of pectoral; two smaller ones on both sides near tip of snout. Skin everywhere close set with velvety prickles, except the fins. Lateral line distinct, armed with spines which are strong and curved backward. Sides with two series of stout curved spines, besides 4 series of small ones. Dorsal fins separate, of moderate height, with ten slender spines; rays I, 12. Anal of 11 rays, opposite soft dorsal. Caudal small, truncate. Pectoral large, of 11 united rays, below which are four simple free ones. Ventral fins present, small, with one small spine and four long rays. Pyloric coeca about four; air bladder absent. Type species: *M. ambulator*.

Marukawichthys ambulator, n. sp.

(New Japanese name: Marukawa-kazika.)

Head, measured to end of opercular flap, $2\frac{3}{5}$ in length without candal; depth $4\frac{1}{10}$ at the tip of the opercular flap, $\frac{9}{10}$ at the insertion of the first dorsal $3\frac{1}{10}$ in head; maxillary $2\frac{9}{10}$. D. X, I–12; A. 12; P. 11+4; lateral line 37. Length of type 190 mm.

Body thick and heavy anteriorly, tapering posteriorly into a long, slender, quadrate caudal peduncle, the length of which is contained $2\frac{1}{10}$ in the head, its depth $4\frac{7}{10}$ in its length. Head very large,

Fig. 1. *Marukawichthys ambulator*, n. g. n. sp. $\times\frac{1}{1}$, ♀.

with a shallow groove at the occiput. Vent slightly in front of middle of body. Eye very large, placed high, its upper margin projecting above outline of head, its diameter $1\frac{1}{5}$ in snout. Mouth horizontal, the lower jaw included, the maxillary not reahing to below anterior margin of eyeball. Teeth villiform, on jaws, vomer, and palatines. Gill-openings broadly united over the isthmus, no slit behind the last gill arch. Gill rakers short, club-shaped, about one on first arch. Pseudobranchiae large. Branchiostegals 6.

Head and body covered with a velvety shagreen. Nasal spines short and sharp; upper rim of orbit with spines, the posterior of which is large and strong, its length contained about $2\frac{4}{5}$ times in eye, with two or three minute branches; sides of the nape with a large bicuspitate spine; opercular spine obscure; preopercle with fine sharp

straight spine, the uppermost of which is contained about 7 times in eye; the second of which about $4\frac{7}{10}$ times in eye, two strong spines at both sides near tip of snout, the anterior one directed forward, the posterior one downward and forward; a strong one on the upper portion of base of pectoral directed upward and backward. Lips thick, without barbel. Sides of body with rows of slender hooked spines; the uppermost row extending from nape to tail; the second row, of smaller spines along immediately above lateral line; the third row along lateral line; the fourth, below the curved portion of the lateral line; the fifth row, of strong spines, but smaller than those of the uppermost, beginning above, but a little anterior to, vent and extending to base of caudal; two insignificant rows arising above upper portion of base of pectoral fin; the sixth on the sides of the ventral portion of the body, beginning above between ventral and vent and extending to the end of anal fin. Lower edge of caudal peduncle with a long groove.

First dorsal high, of slender spines; the fourth spine longest, its length contained about $2\frac{1}{5}$ times in head. Dorsal separate, but close together, the the longest ray (fifth ray) about $1\frac{1}{3}$ in head. Anal shorter than the soft dorsal, the fifth or sixth the longest, about $1\frac{4}{5}$ times in head. Caudal truncate, $1\frac{1}{2}$ times in head. Pectoral fin of two parts; the upper of 11 rays, mostly branched, the longest ray $1\frac{1}{5}$ in head; lower part of fin of 4 separate, simple rays similar to the free appendage in Triglidae, the uppermost slightly longer than the head; the lowermost shortest, shorter than half length of the upper, $2\frac{1}{5}$ in head.

Color in formalin pale brown with about 13 or more irregular cross bands, wider than the interspaces; 3 under spinous dorsal, 5 under soft dorsal, 4 on the tail, one on the base of the caudal fin. There is no remarkable blotch on the head, the snout and the margins of opercles and preopercles somewhat darker. Dorsals pale brown; the first dorsal with 3 remarkable longitudinal dark bands, the outer band darkest; the second dorsal fin with 8 dark bands, the interspace of which forming a pale round spot on the fin membrance. Anal black with 5 oblique pale brown bands. Tip of the caudal black. Pectoral with 6 dark crossbands with regular intervals, but absent on the free rays.

Type is a female obtained off Himi-gun, Toyama Bay, at a depth of 70–300 meters, on muddy bottom, and is deposited in the Zoological Laboratory, Imperial Fisheries Institute, Tokyo.

(*ambulator*, a walker)

Pearl-sac Formation in the Pearl Oyster, *Margaritifera martensii* Dunker.[1]

Tomozô TANAKA[2]

(Received January 22, 1931).

The biologic study of pearl, especially of its nucleus, dates back to the middle of the sixteenth century. But it was not until Küchenmeister, Hessling, and Meckel, in 1856, and Möbius, in the next year, discovered pearl-sacs in some lamellibranchs that intrinsically complicated nature of pearl formation was known to science. The sac in question was described by the authors as a vesicular structure formed in the body of bivalves for secreting pearly

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(1) Contributions from the Zoological Laboratory, Imperial Fisheries Institute, No. 19.

(2) The late Mr. Tomozô Tanaka, assistant professor of zoology, was born on July 25, 1899, in Tokyo as the first son of Mr. Tomoemon Tanaka. His scientific career began in 1921 when he graduated from the Imperial Fisheries Institute by presenting a thesis on the cytoplasmic inclusions of the sexual cells of a daphnid, *Moina macrocopa*. His interest in this cladoceran had continued until he breathed his last and was expressed in the form of several papers published in this journal. Problems of genetics also attracted his attention, joint experiments with me on a fish, *Oryzias latipes*, having been under way. However, he was by far concerned with the study of pearl throughout his research life; his beautiful microscopic preparations of the pearl oyster had accumulated to about twenty thousand in number until they were all reduced to ashes by the quake fire of 1923. The calamity did not suppress his ever ardent zeal which made him succeed to complete several methods of pearl-culture which were announced by the Patent Bureau of our government in 1929 as distinct from all hitherto known. Not satisfied with this attainment, he still devoted much time to purely scientific study of the pearl oyster with special reference to microscopical change of the epithelial layer of the mantle during the pearl formation. The manuscript of the present paper was finished long before his death but another paper on the cytological observations on the pearl-forming organic elements was in preparation in his death bed with assistance of his wife, by whom and a son he is survived. His health declined from September last and kept him from doing his routine work, and on January 13 he was transferred to a hospital where his illness took suddenly a worse turn and he passed away on January 22, 1931. Mr. Tanaka was a brilliant pupil in the class room, a keen observer in the laboratory, and a pleasant colleague to work with. It is a great pity that his aspiring spirit should have lodged in a poor physique which had collapsed before a little bit of his ideal was realized.—*A. Terao.*

substance within it by the epithelial cells which are the same as those lining the mantle. Boutan made public his opinion, in 1902 to 1904, based on his observations on *Mytilus edulis*, to the effect that eggs of certain parasites are responsible for giving rise to a pearl-sac which is at first an invaginated portion of the epithelial layer of the mantle partly enclosing the eggs in it and later it becomes an enclosed pouch situated quite free in the connective tissue of the mantle and produces pearly matter around the foreign bodies. The necessity of inclusion of a nucleus of outside origin for production of pearl was doubted in 1907 by Nishikawa who ascribed the pearl-forming function to the epithelial cells which not only line the mantle but also overlay the adductor muscles and operculum. Rubbel, in 1911, from his study on *Margaritana margritifera*, regarded periostracum contained in the epithelial cells of the mantle as the nucleus of a pearl which is to be formed in a pearl-sac.

For some years past, I had opportunity of examining the pearl and pearl-sac in a Japanese species of pearl oyster, *Margaritifera martensii*, and have obtained the results which stand at variance with those of the previous investigators. The present paper deals with a mode of pearl-sac formation and histologic structure of the mantle of the species in question. It is my pleasant duty to return herewith my hearty thanks to Professor Terao for many acts of kindness given me in various ways.

Material and Methods.

The material on which the present paper is based was obtained from Matoya Bay, Mie Prefecture and was fixed with either formalin, alcohol, saturated solution of corrosive sublimate, Flemming's solution, or Bouin's fluid. One year's sojourn on the shore of that bay enabled me to secure a series of material showing a cycle of seasonal variations, and subsequent visits to the locality afforded opportunities to supplement the material.

Observations.

The epithelial layer of the mantle of *Margaritifera martensii* (Fig. 1, *A* and *B*) consists mostly of large, rounded, vesicular cells which are either circular, ovoid, or elliptical in outline and are so loosely set with each other that they easily fall off or break down when subjected to external stimuli. When this layer is severed from the underlying tissue of the mantle, put

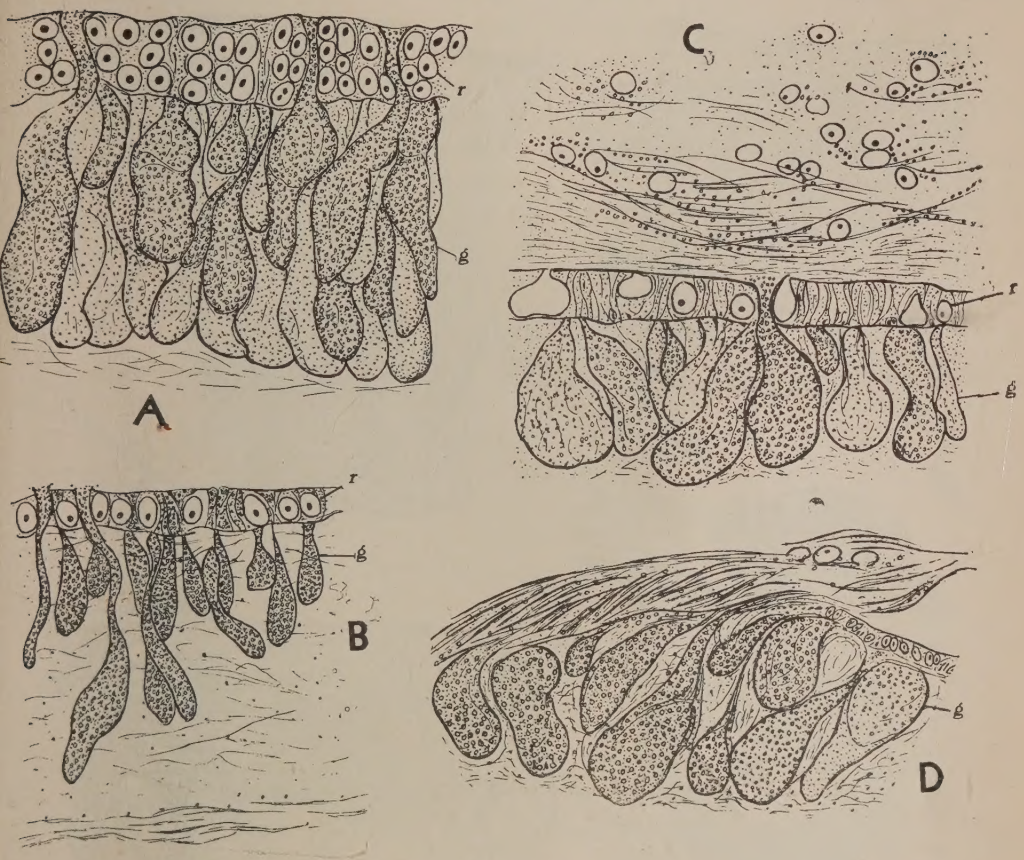

Fig. 1.

Showing transverse sections of the mantle of *Margaritifera martensii*, ×330. *A*, material obtained in early winter; *B*, material obtained in summer; *C*, degeneration of the epithelial layer due to stimuli; *D*, advanced stage of the same; *gl*, unicellular gland; *r*, rounded cell.

around a "pearl-nucleus" in the form of an enclosed pouch, and embedded in the connective tissue of another specimen, it soon crumbles away leaving its blackened disintegration products around the "nucleus". It is clear therefore that the rounded cells differ from the cylindrical cells which mainly constituee the epithelial layer of the mantle of other bivalves in inability to produce pearl. My observations have shown that the numerous knob-shaped

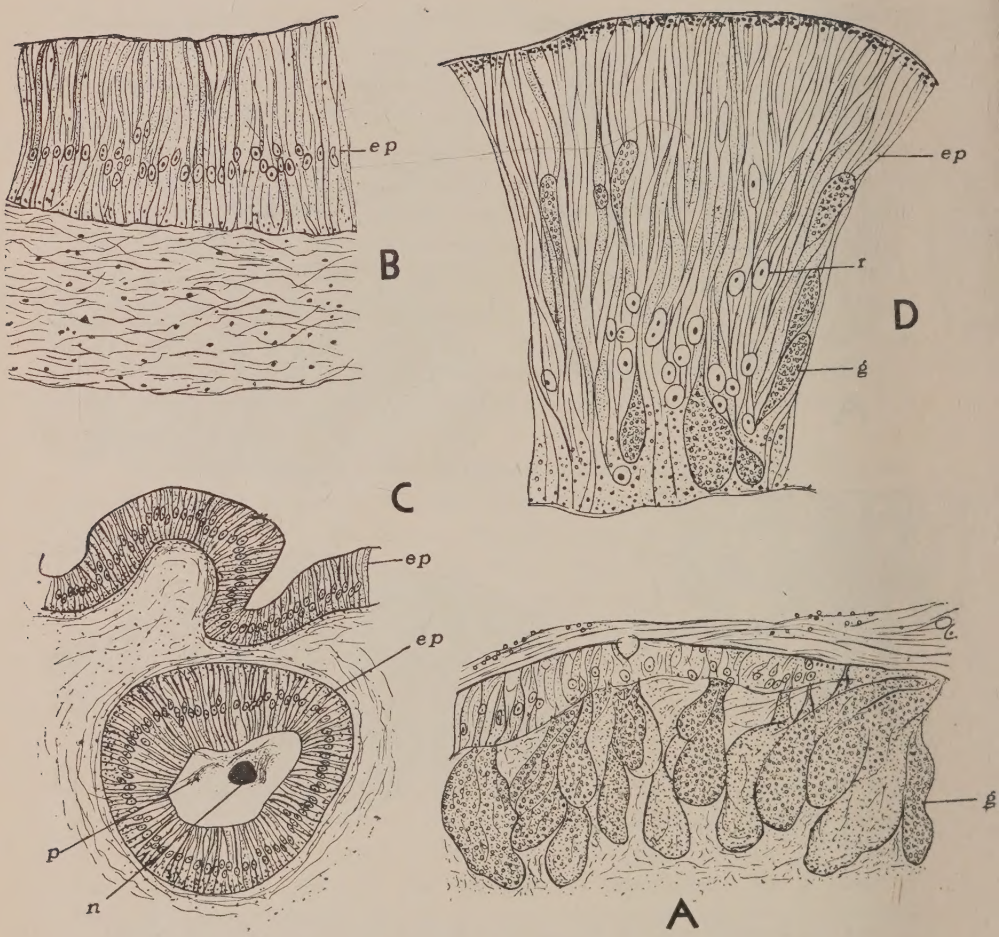

Fig. 2.

Showing transverse sections of the mantle and pearl-sac of *Margarifera martensii*, ×330. *A*, elongated epithelial cells begin to appear; *B*, elongated epithelial cells (*ep*) exclusively line the mant'e; *C*, pearl-sac formed by invagination of the layer of elongated epithelial cells; *D*, elongated epithelial cells are being replaced by rounded cells (*r*) and glands (*g*).

unicellular glands located beneath the rounded cells are responsible in the present species for production of pearly substance, and that a pearl-sac is

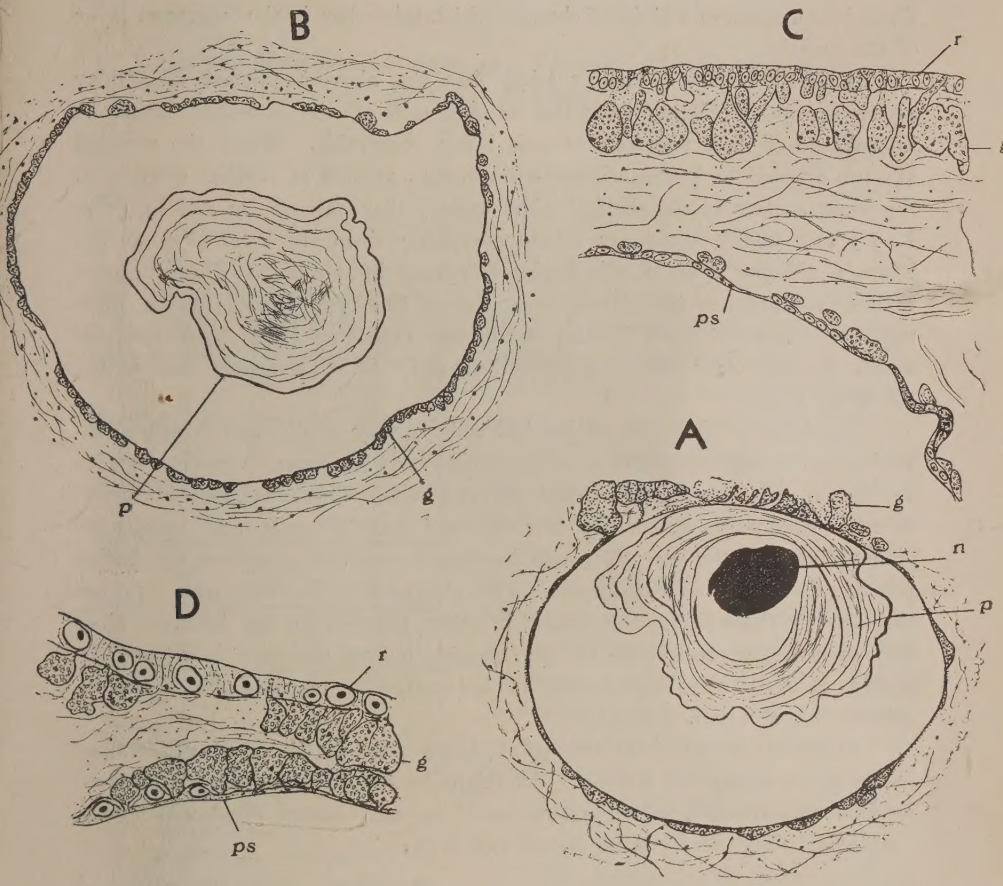

Fig. 3.

Showing transverse sections of pearl-sacs and pearls. *A*, pearl-sac containing a nucleate pearl (*n*), ×120; *B*, pearl-sac with an enucleate pearl (*p*), ×90; *C*, part of a pearl-sac (*ps.*) formed in the connective tissue of the mantle, ×150; *D*, part of a pearl-sac (*ps.*) beneath the outermost layer of the mantle being composed mostly of rounded cells (*r*) and unicellular glands (*g*), ×330.

formed as a result of a series of changes which take place in the outermost layer of the mantle.

It should be first borne in mind that the above-mentioned unicellular glands are quite different from the rounded cells of the outermost layer, no interchange of these two sorts of cells being observable. When the rounded alls are exposed to long-continued stimuli, e.g., growth of certain sponges on the inner surface of the shell of pearl oyster, they fall off by and by (Fig. 1, *C*) and finally disappear almost completely from the layer (Fig. 1, *D*). Then, a different type of cells begins to appear in this layer. Hand in hand with degeneration of the glands, elongation of this type of cells takes place until the outermost layer is compcsed of this type only (Fig. 2, *B, ep.*), for which a term of "elongated cylindical cell" is conveniently used in the following lines.

The layer of elongated cylindrical cells is very elastic and is apt to invaginate in response to contact with any foreign body whatever. Once it starts invagination, an enclosed pouch almost always results. Then, elongated cylindrical cells are gradually replaced by the ordinary rounded cells and unicellular glands and thus the enclosed pouch becomes a complete pearl-sac, producing pearly substance from the glands. The elongated cylindrical cells are not the same as those lining the mantle in other pearl-producing bivalves, since they soon degenerate if external stimuli are removed and they do not produce pearly matter when transplanted in the connective tissue of the mantle together with a "pearl-nucleus".

Attention is called to the point that a pearl is not necessarily formed in the above-mentioned manner. As might be expected, most pearls produced in this way contain a "pearl-nucleus" in each centre, those without the "nucleus" (Fig. 3, *B*) being rarely met with.

On the Relation between the Vacuum and Head Space in Canned Foods.

Hideo WADA.

(Received January 20, 1931).

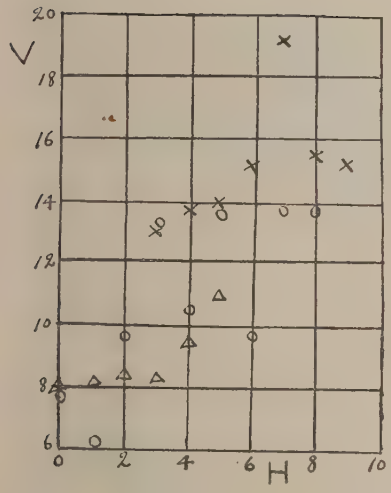

Fig. 1.

V: vacuum in inch.
H: depth of head space in *lu*
○.. Cooked and specially flavoured beef
×.. a kind of cooked broad bean
△.. Cooked mixture of pieces of several vegetables.

E. D. Clark, R. W. Clough and O. E. Shostrom[1] have proved experimentally and theoritically that the vacuum in a canned salmon decreases as the head space increases.

With a view to ascertain whether this relation holds or not in canned foods of our market, the data given by "*Silan-Kandume-Kaikwan-Kenkyûkwai*[2]" on three kinds[3] of the goods, which have large individual differences in head spaces and had been examined in great numbers, were analysed. The relation between the head space and the average value[4] of vacuum calculated from their data[5] is shown in Fig. 1.

Fig. 1 shows that the vacuum in-

(1) E. D. Clark, R. W. Clough and O. E. Shostrom: On the function of vacuum in canned salmon, Pacific Fisherman, May-July, 1923.

(2) A society for the examination of canned food of our market.

(3) Cooked and specially flavoured beef, cooked mixture of pieces of several vegetables, and a kind of cooked broad b an. Each of the three kinds was prepared in tall one-pound can.

(4) Samples of each kind were made by several plants. So the degree of vacuum was quite different even in case the head space was the same, because the exhaustion of air was not performed to the same degree.

(5) Cooked and specially flavoured beef: Canned Food Times, 147–163, **10**, VII and 1 9–125, **10**, VIII. Cooked mixture of pieces of several vegetables: Canned Food Times, 153-161, **6**, VII and 127–137, **6**, VIII. A kind of cooked broad bean: Canned Food Times, 111–115, **8**, VIII.

creases as the head space increases in each of the three kinds selected. Thus we know that the relation given by Clark and his collaborators does not hold in canned foods of our market.

Now, I shall go to put forth the reason of this disagreement[1] between the results of the above-mentioned investigators and myself, and to show that the relation presented in Fig. 1 should result from the nature of the process of exhaustion of air in our plants.

Canned foods in Japan are generally sealed up after they have been held in a definite high temperature bath, $t_2^\circ C$, for a definite time for exhaustion. If the temperature of the upper layer of the contents is $t_3^\circ C$ just before sealing, then the presure of water vapor in head space is equal to the maximum tension, E_3, at $t_3^\circ C$. And as the total pressure in head space is equal to the atmospheric pressure, p_a, the pressure of the remaining air is $p_a - E_3$. So, when the canned food thus sealed is cooled to the room temperature, $t_1^\circ C$, the vacuum, V, in the can should be expressed by

$$V = p_a - (p_a - E_3)\frac{t_1+273}{t_2+273} - E_1$$

$$= p_a\frac{t_1+273}{t_2+273} - E_1 + E_3\frac{t_1+273}{t_2+273}$$

where E_1 is the maximum tension at $t_1^\circ C$.

Accordingly, $dV \propto dE_3$ ..... (1)

When the form and size of the can as well as the quality of the contents are constant, the heat conductivity and specific heat of the contents are regarded to be indifferent to the head space and also the area of conduction of heat is nearly indifferent to it. And as the tall can is cylindrical, the mean temperature of contents and that of their upper layer are nearly the same. Then we have approximately

$$Wd\theta = k(t_2 - \theta)d\tau$$

where θ is the mean temperature of contents after the canned food is held for time τ in a bath at $t_2^\circ C$, W the weight of contents, k a constant.

(1) This disagreement is not due to the method of examination done by "*Sihan-Kwandume-Kaikwan-Kenkyûkwai*," because any systematic error is not likely to occur in the measurement of the weight and head space and the influence of the internal space of vacuum meter upon the reading of vacuum in canned food is neglisible when the head space is over 3 mm. in depth, the values of the constants being as follows:—

internal volume of meter $\fallingdotseq$ 1. 8 c.c.

area of base of tall one-pound can $\fallingdotseq$ 46.5 sq. cm.

$$\text{percentage correction of reading} \fallingdotseq \frac{1.8 \times 100}{46.5 \times \text{depth of head space.}}$$

Integrating the above equation and putting $\theta=t_1$ when $\tau=o$, and $\theta=t_3$ when $\tau=\tau$,

$$\frac{t_2-t_3}{t_2-t_1}=e^{-\frac{k}{W}\tau}$$

or

$$t_3=t_2-(t_2-t_1)e^{-\frac{k}{W}\tau}$$

Differentiating $dt_3=-(t_2-t_1)e^{-\frac{k}{W}\tau}\frac{k\tau}{W^2}dW$

Hence, when the variation of weight is not large in range, we have

$$dt_3 \propto -dW \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

As the density of contents is assumed to be nearly the same for the same kind of canned food, if the weight of contents is W_0 when the head space is zero, and the depth of head space is H when the weight of contents is W,

$$W_0 - W \propto H$$

Then we have $dH \propto -dW$ ..... (3)

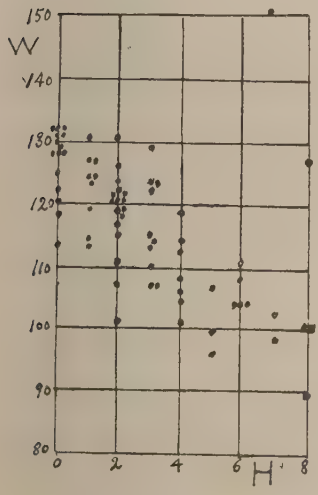

Fig. 2.

W: weight of contents in *monme*.
H: depth of head space in *bu*.

As the nature and concentration of the liquid in a can is assumed to be nearly the same for the same kind of canned food, when the variation of t_3 is not great in range, we have

$$dE_3 \propto dt_3 \quad \ldots\ldots\ldots\ldots \quad (4)$$

From (1), (2), (3) and (4) we have

$$dV \propto dH$$

Hence we may say that, if the four quations (1), (2), (3) and (4) hold good in canned food of our market, the vacuum in that can should increase as the head space increases. Of the four equations, (1) and (4) may need no verification, because they are regarded generally to hold in an equilibrium condition. But (2) and (3) should be varified as in the following lines.

Fig. 2 shows that the equation (3) holds

good in canned foods made by our plants. In this figure, the weight of contents and the head space are plotted from the results[1] of examination of one of the three kinds viz., cooked and specially flavoured beef.

Measuring the change of temperature at the central part of the contents of five cans containing different weight of cooked beef, when they are kept in boiling water for a certain time, we obtained the results given in Table I and Fig. 3. Fig. 4 gives the relation between the weight of contents and

TABLE I.

Temperature at central part of contents in heating for exhaustion.

Weight of contents in *monme.*	Depth of head space in *bu.*	Duration of heating in *minutes*											
		0	5	10	15	20	25	30	35	40	45	50	55
85.	14.0	9	16	66	79.5	86	89.5	92.5	94.5	95	96	97	97.5
		11	37	71	84.5	89	92	95	96	97	97.5	98	98
		10	18	46	64	81	86	91	94	95	96	96.5	97
		19.5	25	54	70	79	85	91	94	95.5	96	97	97
		10	40	75	84	89.5	92	94	95	96	96.5	97	97.5
		9	—	47	63	75	82.5	90.5	95	96	97	98	98
95	9.5	9	10.5	44	67	78	85	89	92	94	95.5	96	97
		11	12	24	54	71	79.5	86	90	92.5	94.5	95.5	96.5
		10	11.5	25	47	72	79	85	89.5	92	94	96	96.5
		10.5	14	34.5	60.5	76	84.5	89	91.5	93.5	95	96	96.5
		10	16	52	71	79.5	85	90	92.5	94	95.5	96	97
105	9.5	9	10.5	22	42.5	57	69	77	83	87.5	90.5	92.5	94.5
		11	13	30	55.5	70	80.5	85	89.5	92	94	95.5	96
		9.5	10	21.5	41	55	67	75.5	82	87	90.5	93	94.5
		10	—	—	46	67.5	72	81	86.5	90	92.5	94	95.5
		10	11	25	49	63.5	75	82	87	89.5	92	94	95.5
115	4.5	9	9.5	12	23	37	51	64	72.5	80	85	89.5	92
		11	11.5	15	25	39	50.5	64	72	79.5	85	89.5	92
		10	11	16	28.5	53	62	70.5	79	85	89	91.5	93
		10.5	11	16	31	49	61	72	79	84	88	91	93
		10	—	25	46	60	70	79	84.5	88	92	94	95
		10	—	—	29	46	56	68.5	76	82	87	90	92
		9	10	17	33	50	63	72	79.5	85	89.5	92	93.5
125	4.0	9	9.5	12	22.5	34	46.5	58 5	68.5	76	81.5	86	89.5
		11	11	14.5	25	39	50.5	62.5	69.5	76	82.5	87	90
		10	11	15	28	50	61	70	77	82	87	90	92
		10.5	—	—	27	43	56	67	74	80	85	89	91
		10	11	18	32	45	55	67	75.5	81	86.5	89.5	92
		10	11	16.5	30	46.5	56 5	67.5	74.5	79.5	85	89	91
		9	10	17	31.5	47	60	69	76	81.5	87	90	92

(1) Cooked and specially flavoured beef: Canned Food Times, 147–163, **10**, VII and 109–125, **10**, VIII.

the temperature at the central part after the heating 30 minutes with reference to Table I; it shows that the temperature decreases as the contents increase, as expressed by the equation (3).

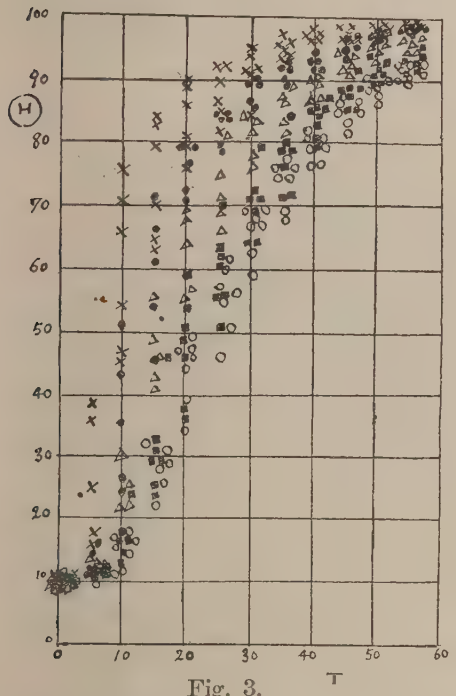

Fig. 3.

Ⓗ: temperature at central part of contents in °C.

T: duration of heating in minutes.

×...Weight of contents 85 *monme*, ● .. 95, △ .. 105, ■ .. 115, ○ .. 125.

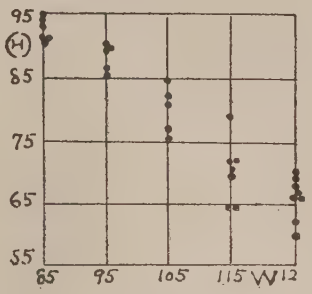

Fig. 4.

Ⓗ: temperature at central part of contents in °C.

W: weight of contents in *monme*.

Thus we see that the vacuum in canned foods of our market should increase as the head space increases.

Clark and others deduced the relation between the vacuum and head space in canned salmon on assumption that the temperature of the central part of the contents is the same irrespective of the depth of head space. In other words, they assumed that the depth of head space is mainly due to the difference of the density of contents, and that the weight of the contents is constant. And, in their experiment, by which the result theoretically deduced was verified, the canned foods were sealed up when the temperature of the central part of the contents reached to a definite value irrespective of duration of time. But on the other hand, the canned food in our plants is in general sealed up after a definite time of heating, as stated above, and the depth of head space is mainly due to the weight of contents as the

density of contents is nearly constant. This is the reason whey their result does not hold good for canned foods of our market.

In conclusion, the author's most cordial thanks are due to Prof. Tauti for his kind and earnest guidance and to Prof. Miyama and Asst. Prof. Kawaguti for their helpful advices and to Prof. Matuike for his valuable criticism.

August, 1930.

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Circulation of Air in a Cold-Storage Warehouse. I. Preliminary Experiments on Convection Current in a Rectangular Chamber Cooled above and Heated below.

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Preliminary experiments for the study of circulation of air in a cold-storage warehouse were undertaken by I. Hirose, F. Narisawa, H. Wada and the writer, with a view to obtain general condition, which must be fulfilled in the experiments with models, and also to find the fundamental feature of distribution of humidity in convection current. In the present paper discussions about some of the results obtained will be given.

Method of experiments. Fig. 1 shows the apparatus used in the experiments. The whole apparatus is a rectangular box without upper and lower sides, the flank side of which is made of wooden plank, and the upper halves of its front and back sides are made of glass plates (g_f and g_b), while the lower halves of wood. The box is horizontally divided into three parts by two brass plates (M_1 and M_2), having a thickness of $3^{mm.}$. In the upper part a tank made of zinc plate is put in. The middle part is divided into three compartments by two glass plates (g_1 and g_2) placed parallel to the front and back sides, at about equall distances. The middle compartment thus formed is again separated into three parts by glass plates put parallel to the flank side, leaving a certain room on both sides. The rectangular room thus formed in the middle compartment of the box occupies the main part of the whole apparatus. Hereafter I shall call it the main chamber for the sake of brevity. The size of the main chamber may be changed by uplifting the upper metal plate and in consequence by exchanging glass plates. In the lower part of the box, whose four sides are made of plank, a coiled nichrome heating wire is stretched in parallel rows on a horizontal plane at a distance of a few centimeters beneath the lower brass plate. Three similar apparatus A, B and C of different sizes were constructed having the metal plates $30^{cm.} \times 10^{cm.}$ in A, $45^{cm.} \times 15^{cm.}$ in B and $60^{cm.} \times 20^{cm.}$ in C in size respectively.

The lower brass plate is heated from below by supplying electric current to the heating wire (resistance=20.5$^{\text{Ohms}}$ in A, 28.5$^{\text{Ohms}}$ in B and 4.9$^{\text{Ohms}}$ in C, voltage=2$\sim$135$^{\text{volts}}$), while the upper brass plate is cooled from above by filling the tank with water, the free surface of which being exposed to the surrounding air. In some cases, melting ice was put in the tank. The thickness, d, of the main chamber is made comparatively smaller than the height, h, and the breadth, b, so as to make the motion of air in the main chamber nearly to be two-dimensional. The motion of air has been observed from the front of the chamber.

With a view to indicating the motion of air in the main chamber, the smoke of "senkô", a common Buddhist's insense in the form of a filamental rod, was used. The convenience of the use of this smoke for such purpose as in the present experiments have been already reported by Prof. T. Terada and M. Tamano.(1) A reservoir of the smoke is situated beneath the heating wire in the lower part of the box mentioned above, and is separated by an obliquely set glass plate from the part where the heating wire is supported. The smoke from the reservoir is led into the main chamber from its rear part through a slit, a few millimeters wide, between the back glass wall (g_2) and lower brass plate (M_2) by passing through a rectangularly bent chimney (C). The excess of the smoke might leak out slowly through the corner of the chamber, but this leakage could hardly be recognized owing to the rapid diffusion of patches of smoke in the convection current. When the electric current is supplied to the heating wire for an hour or more, the general circulation in the main chamber practically becomes stationary, though accompanied by a number of superposed irregular turbulences. Observations have been concerned exclusively to such stationary convection currents.

The outer glass plate in front of the main chamber (g_f) is prepared to have a narrow opening (p) on its lower edge, and the lower edge of the inner front glass (g_1) is lifted up by small supports so as to make a slit (s). In order to measure the temperature in the convection current, a junction (J) of a thermocouple held by a thin glass tube is inserted in the main chamber through the opening (p) and the slit (s) just now mentioned, as shown in Fig. 1, (a) and (b). The leading wires of the junction are bent at right angles at the slit (s) and may be moved in any way along the inside of the inner front glass (g_1). The upper part of the leading wires is bent at the end of the

(1) T. Terada and M. Tamano: Further Researches on Periodic Columner Vortices Produced by Convection. Tôkyô, T. D. Kôkûhôkoku. Vol. IV, No. 53, (1929).

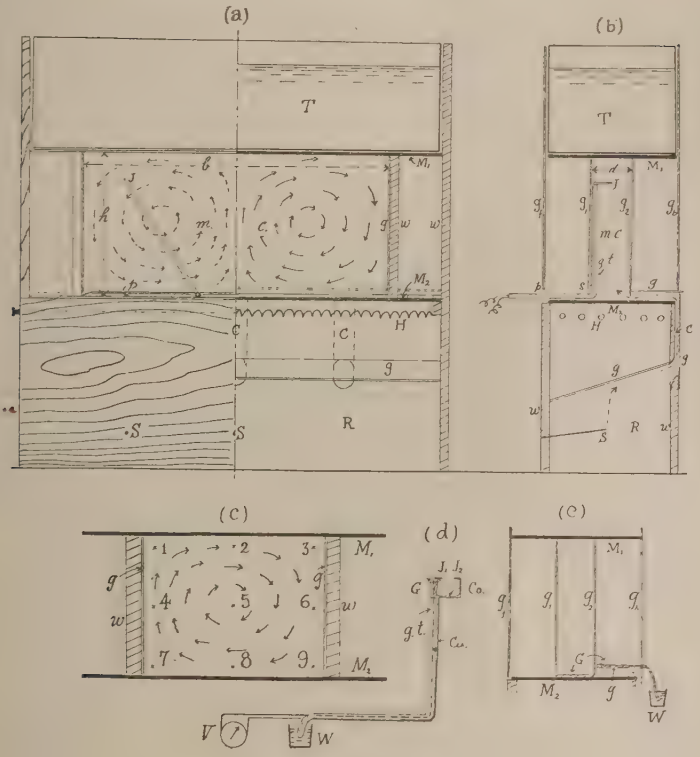

Fig. 1.

(a) and (b): the elevation and the side view of the whole apparatus. (c): nine points, where the humidity was measured. (d): hygrometer. (e): main chamber with moist gauze. (side view).

m. c.: main chamber; g: glass plates; M_1 and M_2: brass plates; *w*: wooden planks; T: water tank; H: nichrome heating wire; R: reservoir of smoke; S: "Senkô"; C.: chimney; W: reservoir of water; G: moist cotton gauze; *g. t.*: glass tube; Cu: copper wire; Co: constantan wire; J: thermojunction; V: galvanometer.

glass tube at right angles, and reaches the half of thickness of the main chamber.

For the measurement of humidity, several devices were tried, and finally a "wet-and-dry-junction-thermocouple" was adopted as a hygrometer. Fig. 1, (d) shows the hygrometer. A thermocouple is supported by a glass tube. The two junctions (J_1 and J_2) are put face to face at a distance of $6^{mm.}$ on the same line at right angles to the glass tube, and one of them is kept con-

stantly moist by a wrapping of cotton gauze, to which a cotton wick is attached passing through the glass tube and dipping in a reservoir of pure water. The hygrometer is put in the main chamber just in the same way as the thermo-junction used as thermometer, by which the temperature was measured at every point where the reading of the hygrometer was taken. The hygrometer was frequently calibrated, being compared with the common psychrometer in the laboratory room, and the reading thus gives the corresponding wet-bulb-depression, the thermometer giving the dry-bulb temperature. As soon as the result of a calibration became discordant with that formerly obtained, a new wrapping was substituted. In our experiments the junctions of the hygrometer are kept apart more than $5^{mm.}$ from any glass or brass plate around the main chamber, because it was ascertained by a preliminary experiment in the laboratory room, that the reading of the hygrometer is gradually lessened as the junctions approach to any glass or brass plate within about $5^{mm.}$, while the ordinary psychrometer shows constant humidity in the laboratory. The relative and absolute humidity, r and ρ' respectively, are calculated using a meteorological table, which gives the values obtained from Angot's formula. As the main chamber used for experiments was a small closed chamber, the constants in the formula of psychrometer might have a larger value than in Angot's. But as the air in the main chamber is in turbulent motion with the general velocity of a few cms. per second, the effect just stated above will, roughly speaking, nearly be cancelled. Even if the absolute values in the calculation of r and ρ may not be very accurate, their relative values, at least, will fairly well represent the actual feature of distribution of humidity.

The following three series of experiments were tried.

The first series of experiments was mainly intended to find the relation of velocity of circulation to the difference of temperature on both brass plates, θ_0, with respect to different convection currents in the cases where the shape of main chamber is similar to each other. Three similarly shaped main chambers were adopted having the size I, II, and III, *viz.* I, $h=10^{cm.}$, $b=22^{cm.}$, $d=2.7^{cm.}$; II, $h=15^{cm.}$, $b=33^{cm.}$, $d=4^{cm.}$; and III, $h=20^{cm.}$, $b=44^{cm.}$, $d=5.3^{cm.}$. In any one of these chambers it was observed that two similar symmetrical vortices appear in the stationary state. They were quite stable ascending, in some cases, at the middle of the chamber, while in others along the side walls. The velocity from point to point can hardly be measured with any accuracy. For the present, we were satisfied with a rough estimation of the period of general circulation, T, with a stop watch in hand, by following the motion of accidental patches of smoke moving along an orbit near the margin of a vortex. The

from of stream-lines of general flow was sketched, and the temperature at several points on both brass plates was measured.

In the second series of experiments, the change of form of vortices was observed when the shape of the main chamber was varied. Main chambers, used, have the height and thickness same as those of I or II in the first series while their breaths were made to change. Cases, in which θ_o was different from each other were compared. When the breadth, b, increases gradually, the number of vortices having the height, h, same as the main chamber increases one by one, and almost suddenly when the ratio b/h passes a series of certain values. In some cases, when $b/h<1$, four small vortices, two by two, were observed in a rectangular arrangement. Stream lines of the vortices were sketched.

In the third series of experiments, main chambers having the size I′ $h=10^{cm.}$, $b=12\sim13^{cm.}$, $d=2.7^{cm.}$, and II′ $h=20^{cm.}$, $b=26^{cm.}$ and $d=5.3^{cm.}$, were used. In each of these main chambers a single voltex appeared in stationary state. The form of the voltex was sketched. At nine points 1, 2, ..., 9 in Fig. 1, (c), the humidity r_i ($i=1, 2, \ldots, 9$), ρ'_i ($i=1, 2, \ldots, 9$) and temperature θ'_i ($i=1, 2, \ldots, 9$) were measured. In a few cases where the high humidity was required, a sheet of cotton gauze was laid on the lower brass plate in the main chamber, which was kept moist in a constant and nearly uniform condition with some cotton wicks, the ends of which were dipped into a reservoir of pure water, as shown in Fig. 1, (e). In these cases, water vapour in the main chamber is condensed on the cooled upper brass plate and on the upper part of four glass walls. The water drops thus condensed were, at times, removed by gently sweeping the surfaces of the plates with dry cotton cloth.

Results of Experiments. Summarizing the result of experiments, we learn the following facts.

(i) When the shape of any two chambers is similar, the form of vortices in them and the distribution of the relative values of temperature as well as of absolute humidity are quite similar, irrespective of the difference in size of the chamber, or difference in θ_o.

(ii) In any chamber the average velocity of circulation is nearly proportional to $\theta_o^{\frac{1}{2}}$.

(iii) The absolute humidity, ρ', is almost uniform in a stationary vortex. It is slightly higher in the lower part of the vortex than in the upper.

(iv) The relative humidity, r, is slightly lower in the ascending current than in the descending.

Discussion. As regards the relation of dynamical similitude of steady

natural convection, investigations were made by Boussinesq[1] and other authors. The result is as follows:

The relation of similitude is obtainable only when the condition, that

$$l \propto \left(\frac{\theta_o g a C}{K\nu}\right)^{-\frac{1}{3}}, \quad \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

holds on the boundary of any similarly shaped bodies in the working fluid. In this equation,

l represents the linear dimension of the boundary;
θ_o, the difference of temperature between any two points on the boundary taken in the similar position for different bodies,
g, the acceleration of gravity;
a, the thermal expansion coefficient of the working fluid;
C, the heat capacity per unit volume „ „ „ „ ;
K, ths conductivity of heat „ „ „ „ ;
and ν, the kinematical viscosity „ „ „ „ .

Under such conditions the velocity of circulation, v, satisfies the relation:

$$v \propto \left(\frac{\theta_o g a K}{C^2 \nu}\right)^{\frac{1}{2}}. \quad \cdots\cdots\cdots\cdots\cdots\cdots (2)$$

With the results of our experiments, it can, of course, be verified that this relation is satisfied. But, besides, our results seem to show the unnecessity of the restriction (1) approximately. In such cases as in our present experiments, the motion of the fluid is, as already mentioned, turbulent, the general flow being accompanied by an irregular, secondary, eddy motion. Hence for the general flow, the following equations will be applied, under the same assumptions as in Boussinesq's theory regarding the effect of change of density due to difference in temperature, etc.:

$$\left.\begin{aligned} &1.\quad div\mathfrak{V} = 0, \\ &2.\quad \frac{D\mathfrak{V}}{Dt} = -\frac{1}{\rho_o} grad P + g a \theta \mathfrak{k} + \{div(\nu\, grad)\}\mathfrak{V}, \\ &3.\quad \frac{D\theta}{Dt} = div\left(\frac{K_e}{C} grad\theta\right). \end{aligned}\right\} \quad \cdots\cdots\cdots\cdots (3)$$

In these equations $\mathfrak{V}$ is the velocity of the general flow; θ, the temperature measured by taking the temperature of the upper plate as origin; t, the time; ρ_0, density of the air at $\theta = 0$; $P = p + g\rho_0 z$, p being the pressure; z, the vertical coordinate, positive direction of which is taken upward; $\mathfrak{k}$, the unit vector in the

(1) Boussinesq: "Théorie Analitique de la Chaleur." Tom. II, p. 177, (1903).

z-direction; and g, α, and C, have the same meaning as in Eq. (1). The coefficients ν_e and $\frac{K_e}{C}$ are, here, the eddy diffusivity, D_e, having far greater values than ν and $\frac{K}{C}$. At a point in the fluid those coefficient, ν_e and $\frac{K_e}{C}$, are given by the expression:

$$D_e \equiv \frac{K_e}{C} = \nu_e = \frac{1}{A}\int\int_{(A)} \delta l_n w_n dS, \quad \cdots\cdots\cdots\cdots\cdots (4)$$

where A is the area of a small plane, S, imagined at the point; w_n, the component of the velocity—perpendicular to S—of the eddy motion; and δl_n, the component of displacement—perpendicular to S—of the particle of air due to the eddy motion, which takes place in a certain small interval of time, δt. The value of D_e varies as the intensity of eddy motion does.

For such convections as in our experiments, it will be natural to assume that if the general convections are similar the velocity of eddy motion varies as the velocity of the general motion, v, and the dimension of each eddy varies as the dimension of the general circulation, l. Then from Eq. (4), it follows that

$$D_e \propto lv.$$

In order that the circulation of air in the two similar chambers, (1) and (2), are similar in the stationary state, and, besides, the relations

$$(x, y, z)_{(1)} = L(x, y, z)_{(2)},\ \mathfrak{V}_{(1)} = V\mathfrak{V}_{(2)},\ \theta_{(1)} = \Theta\theta_{(2)},$$

$$\text{and}\quad \left(\frac{P}{\rho_o}\right)_{(1)} = \Pi\left(\frac{P}{\rho_o}\right)_{(2)}$$

are satisfied, we must have

$$V^2 = \Pi = \Theta L, \quad \cdots\cdots\cdots\cdots\cdots (5)$$

from the condition that the Eq. (3) must hold good for both chambers, provided that the relations,

$$\left(\frac{K_e}{C}\right)_{(1)} = LV\left(\frac{K_e}{C}\right)_{(2)} \text{ and } (\nu_e)_{(1)} = LV(\nu_e)_{(2)}, \quad \cdots\cdots (6)$$

are assumed.

Equation (5) states that, whenever the distribution of temperature is similar on the boundary of both similar chambers, the circulation of air in each chamber becomes similar and then[1]

$$v \propto (\theta h)^{\frac{1}{2}} \text{ and } \frac{P}{\rho_o} \propto \theta h. \quad \cdots\cdots\cdots\cdots\cdots (9)$$

(1) A relation of the same form as (9) can be obtained from Eqs. (1) and (2), but the restriction (1) can be removed only when we assume (6).

Hence, if T denotes the period of circulation along some similar orbits,

$$T \propto \left(\frac{h}{\theta_o}\right)^{\frac{1}{2}} \quad \text{..... (10)}$$

Tab. I and Fig. 2 show the relation between $log\ T$ and $log\ \frac{h}{\theta_o}$ calculated from the result of our experiments. The relation is linear, and from the straight line in Fig. 2 we have the value 0.5 for m in the relation

$$T = T_o\left(\frac{h}{\theta_o}\right)^m,$$

as shown in Tab. I. So far as the period of circulation in the region of turbulence is concerned, our assumptions seem to be tenable.

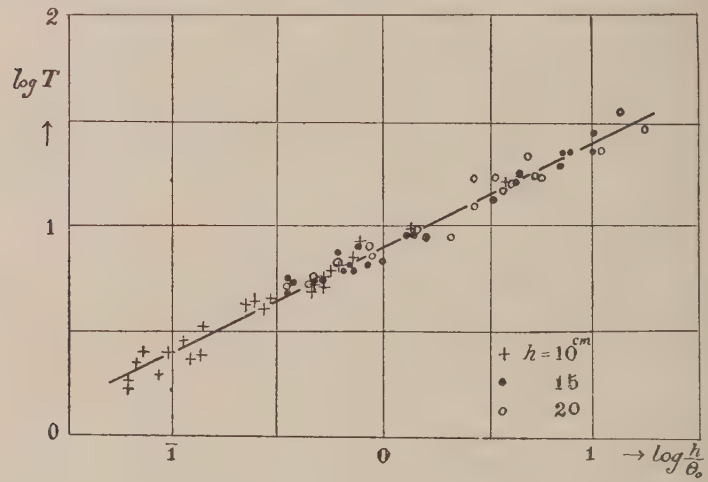

Fig. 2.

T, period of general circulation;
h, height of the main chamber;
θ_o, temperature difference on both brass plates, M_1 and M_2.

With the idea that the eddy diffusivity plays an important role in the circulation, we can proceed to the discussion about the distribution of humidity. If ρ_w denotes the mass of water vapour per unit mass of moist air, *i. e.* the specific humidity, we have the following equation:

$$\frac{D\rho_w}{Dt} = div(D, grad\rho_w).$$

Hence, ρ_w and θ satisfy the same differential equation. In the experi-

ments where moist gauze is laid on the lower brass plate, and the water vapour is condensed along the cooled upper brass plate, as formely described, the boundary conditions are such that

$$\rho_w=\rho(0) \text{ and } \theta=0 \text{ on the upper brass plate,}$$
$$\rho_w=\rho(\theta_o) \text{ and } \theta=\theta_o \text{ ,, ,, lower ,, ,, ,}$$
and $$-\frac{\partial\rho_w}{\partial n}=0 \text{ and } \frac{\partial\theta}{\partial n}=0 \text{ on the side walls,}$$

where $\rho(x)$ denotes the value of ρ_w in the saturated condition at a temperature, $\theta=x$; and n, the normal to the surface of walls. In these cases, therefore, the boundary conditions are similar for ρ_w and θ, and consequently the distribution of ρ_w and that of θ must be similar. Strictly speaking, there is against the surface of boundary a region free from eddies, which is to be excluded from our consideration. The boundary conditions must be considered on the surface between this region and the eddy one. But parallelism between the boundary condition of ρ_w and that of θ may nearly be satisfied.

From the data of experiments, the values of

$$\sigma_i\equiv\frac{\rho'_{w_i}-\bar{\rho}_{w_a}}{\bar{\rho}_{w_b}-\bar{\rho}_{w_a}}, \ (i=1, 2, \ldots\ldots, 9),$$

and

$$t_i\equiv\frac{\theta'_i-\bar{\theta}_a}{\bar{\theta}_b-\bar{\theta}_a}, \ (i=1, 2, \ldots\ldots, 9),$$

are calculated, where $\rho'_{w_i}=\rho_i'\left(1+\frac{\theta'_i}{273}\right)$, ρ'_i being the absolute humidity and θ'_i the temperature at the nine points, 1, 2, ..., 9, in Fig. 1, (C); $\bar{\rho}_{w_a}$=mean value of ρ'_{w_1}, ρ'_{w_2} and ρ'_{w_3}; $\bar{\rho}_{w_b}$=mean value of ρ'_{w_7}, $\rho_{w'_8}$ and $\rho_{w'_9}$; $\bar{\theta}_a$=mean value of θ'_1, θ'_2 and θ'_3; and $\bar{\theta}_b$=mean value of θ'_7, θ'_8 and θ'_9. Tab. II and Fig. 3 show the values of σ_i and t_i, obtained in four experiments. In Fig. 3, the relation between the mean values of σ_i and t_i is shown to be similar. This is explainable from our consideration.

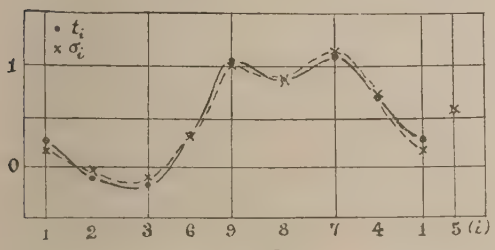

Fig. 3.

i, name of the nine points in Fig. 1. (C);
σ_i, relative values of the specific humidity;
t_i, relative values of the temperature.

Before concluding, the writer wishes to express his

warmest thanks to Dr. M. Tauti for the constant guidance and valuable advices rendered to him. The writer's cordial thanks are also due to Messrs. I. Hirose, F. Narisawa and H. Wada.

Summary.

1. Two-dimensional vortices produced by convection in three similar rectangular chambers are proved to be practically similar with respect to their form, distribution of temperature and that of absolute humidity.

2. The relation

$$T = T_0\left(\frac{h}{\theta_0}\right)^{\frac{1}{2}}$$

is found among the period of general circulation, T, the height of each chamber, h, and the temperature difference on two brass plates, making the upper and lower sides of each chamber, θ_0.

3. A similitude between the distribution of temperature and that of specific humidity in the circulation was found in certain special cases.

4. An explanation was given to the preceding facts, the eddy diffusivity being taken into consideration.

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Imperial Fisheries Institute.

Table I.

h cm.	θ_o °C	T sec.	$\log \frac{h}{\theta_o}$	$\log T$
10	2.6	15.9	0.59	1.20
	7.4	9.5	0.13	0.98
	13.0	8.3	$\bar{1}.89$	0.82
	13.4	7.1	$\bar{1}.87$	0.85
	16.1	6.5	$\bar{1}.79$	0.81
	17.9	6.2	$\bar{1}.75$	0.79
	19.1	5.1	$\bar{1}.72$	0.71
	19.6	5.2	$\bar{1}.71$	0.72
	19.7	5.7	$\bar{1}.71$	0.76
	21.4	5.3	$\bar{1}.67$	0.72
	21.4	4.8	$\bar{1}.67$	0.68
	33.7	4.4	$\bar{1}.47$	0.64
	36.5	3.9	$\bar{1}.44$	0.59
	40.5	4.3	$\bar{1}.39$	0.63
	45.0	4.1	$\bar{1}.35$	0.61
	71.1	3.3	$\bar{1}.15$	0.52
	72.3	2.4	$\bar{1}.14$	0.38
	80.5	2.3	$\bar{1}.09$	0.36
	87.3	2.9	$\bar{1}.06$	0.46
"	101.6	2.5	$\bar{2}.99$	0.40
	115.2	1.9	$\bar{2}.94$	0.28
	138.2	2.5	$\bar{2}$ 86	0.40
	149.0	2.3	$\bar{2}.83$	0.36
	156.9	1.85	$\bar{2}.80$	0.23
	160.5	1.67	$\bar{2}.80$	0.22
15	1.4	28.5	1.01	1.46
	1.5	21.2	1.00	1.33
	1.9	23.3	0.90	1.37
	2.0	23.6	0.88	1.37
	2.1	19.5	0.86	1.29
	3.4	18.5	0.64	1.27
	3.6	15.7	0.62	1.20
	4.7	13.3	0.51	1.12
	9.3	8.9	0.21	0.95
	10.3	9.4	0.16	0.97
	11.5	9.4	0.12	0.97
	15.5	6.6	$\bar{1}.99$	0.82
	17.2	6.5	$\bar{1}.94$	0.81
	18.1	8.0	$\bar{1}.89$	0.90
15	20.4	6.2	$\bar{1}.87$	0.79
	21.3	6.6	$\bar{1}.85$	0.82
	23.5	6.2	$\bar{1}.81$	0.79
	24.5	7.6	$\bar{1}.79$	0.88
	29.3	5.4	$\bar{1}.71$	0.73
	31.4	5.4	$\bar{1}.68$	0.73
	40.7	5.4	$\bar{1}.58$	0.73
	41.7	5.6	$\bar{1}.56$	0.75
	42.8	4.9	$\bar{1}.55$	0.69
20	1.1	30.1	1.26	1.48
	1.5	35.7	1.13	1.55
	1.8	23.3	1.05	1.37
	3.5	17.0	0.76	1.23
	3.8	17.5	0.72	1.24
	4.1	22.0	0.69	1.34
	5.2	15.7	0.59	1.20
	5.4	14.9	0.57	1.17
	6.1	16.4	0.52	1.22
	7.7	12.5	0.42	1.10
	7.8	15.5	0.41	1.19
	9.5	11.0	0.32	0.93
	14.0	9.5	0.16	0.98
	22.6	7.1	$\bar{1}.95$	0.85
	23.2	7.9	$\bar{1}.94$	0.90
	32.9	6.6	$\bar{1}.79$	0.82
	43.2	5.7	$\bar{1}.67$	0.76
	45.4	5.1	$\bar{1}.65$	0.71
	57.3	5.0	$\bar{1}.54$	0.70

$$T = T_o \left(\frac{h}{\theta_o} \right)^m$$

h cm.	T_o sec.	m	$\log T_o$
10	7.6	0.51	0.88
15	7.9	0.49	0.90
20	8.1	0.50	0.91
	7.9	0.50	0.90

Table II.

	i / No.	1	2	3	4	5	6	7	8	9
θ_i' [°C]	1	31.2	29.9	29.9	33.6	33.3	32.5	35.9	34.6	35.9
	2	30.8	30.8	30.1	32.7	32.2	31.5	33.6	32.6	32.6
	3	30.9	28.7	29.0	31.4	30.6	30.0	32.4	31.6	32.1
	4	32.2	30.6	30.1	34.5	33.0	32.3	35.8	34.6	35.0
φ'_{wi} [gr./m.³]	1	314	324	322	373	374	360	418	402	404
	2	323	335	324	366	371	338	384	367	383
	3	354	312	315	344	337	335	357	336	352
	4	347	321	311	400	367	349	427	419	424
t_i	mean	0.24	−0.10	−0.18	0.69	0.56	0.33	1.08	0.86	1.05
σ_i	"	0.15	−0.03	−0.11	0.71	0.57	0.32	1.14	0.86	1.01

A Physical Method of Testing the Freshness of Raw Fishes.

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Ikurô Hirose and Hideo Wada.

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Tests of freshness of raw fishes are usually based on the examination of either discoloration of their gills and eye-balls or of exudation of bad smell from their body; but by this method we can only distinguish stale from fresh. Scientific tests of the same rest on the chemical analysis of amino-acid and ammonia or on the estimation of PH of the material, but practically these are applicable to a few specimens taken out from the whole. Fish dealers learn from their experience a method of testing the freshness which is based on the sensation felt by the tip of a finger pressed on fish body and thus to some extent they can estimate the freshness of each fish accurately. The present study was done to make out the principle of the finger-tip method and to get a freshness-testing instrument based on that principle.

The sensation felt by a finger-tip pressed on a fish can be supposed to depend mainly upon the physical character, particularly the elasticity of the fish muscle. It is well known that a change in the elasticity arises in the course of the decomposition of fish. So, by the finger-tip method we may judge the freshness in terms of the elasticity.

To decide the elastic properties, we measured three quantities as follows: (i) the force needed to give a certain deformation on the surface of fish, (we shall call it the force of deformation in the following lines) (ii) the degree in which a fish returns to its original shape as soon as the force is removed, (the degree of return) and (iii) the time required to get rid of a certain portion of a given deformation (the rapidity of return).

To determine the force of deformation, a glass sphere 1.35 cm in dia. (Fig. 1, A) is pressed by a spring on a fish as shown in Fig. 1, A′ and the contraction of the spring is observed. To determine the degree and rapidity of return, a test tube (Fig. 1, B) is pressed on a fish as deep as 5 mm;

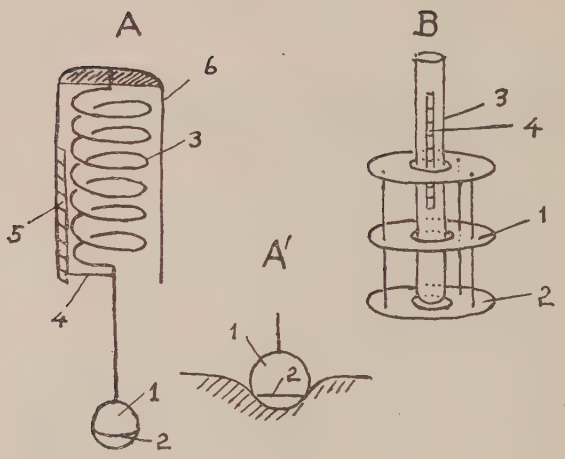

Fig. 1.

A, A′: 1, glass sphere; 2, carved circle; 3, spring; 4, pointer; 5, scale; 6, glass tube.
B: 1, frame; 2, base; 3, glass tube; 4, scale.

and then the distance of return and the time required for the return to take place as far as 4 mm are observed when the tube is set free.

The values obtained by this method can easily be seen to be different at various spots of a fish body. So, by the preliminary experiment the extent of its surface area which is to give the same observational value was firstly determined and in the subsequent experiment to be stated below the observation was limited in that portion of fish body. As a deformation thus once set on the material has a conceivable effect for a few days later, it was avoided to repeat the experiment on the same area within a few days.

Table I.

Hours after preparation	Force of deformation in gr.				Degree of return in mm.			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
17.8	702	732	723	723	4	4	5	5
26.3	702	732	723	723	4	4	4	4
41.1	423	423	440	440	4	4	4	4
50.1	350	350	376	395	4	4	4	4
66.3	290	290	320	305	4	4	4	4
73.9	245	265	290	278	4	4	4	4
89.5	235	220	265	265	4	4	4	4
97.5	203	203	220	220	4	4	4	4
113.0	135	135	177	168	4	4	4	4
137.0	135	135	135	135	4	4	4	4

Remark (1) Values obtained in the preliminary experiment are as follows:
Force of deformation=168 gr. and degree of return=5 mm.
(2) Rapidity of return is nearly constant: $1\frac{1}{5}$ sec.
(3) Temperature of the storage: 6~11°C.

Five carp, nearly same in size, were killed and scaled. One of these carp was used for the preliminary experiment and the remaining four were stored immediately in a cold-storage. The force of deformation, the degree and rapidity of return were measured on the stored fishes twice a day. The result of measurement are summarized in Table I.

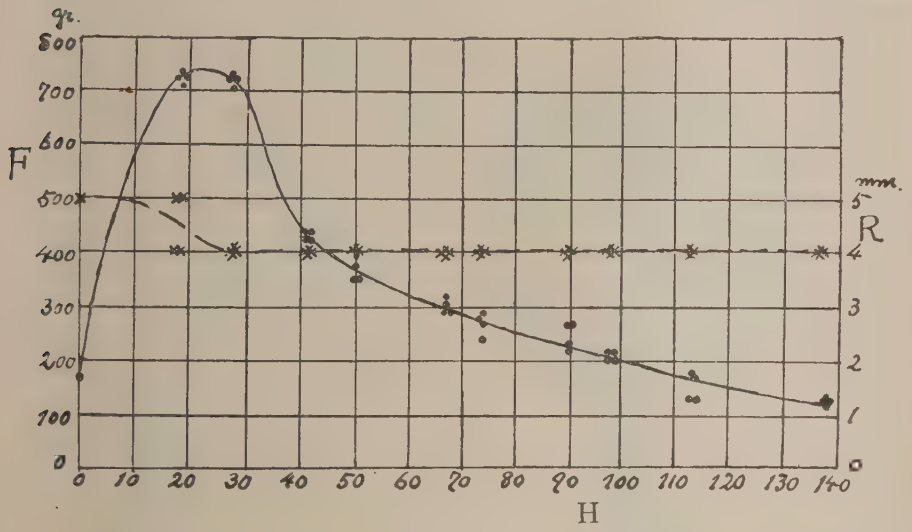

Fig. 2.

Force of deformation, F, and degree of return, R, in relation to hours after preparation, H.
●.....force of deformation, F.
×.....degree of return, R.

Fig. 2 shows the force of deformation and the degree of return in relation to time in hours after preparation. In this figure, we see that the return is nearly perfect until rigor mortis takes place, but after that time it is imperfect, and that the force of deformation increases until it reaches to a maximum in rigor mortis and after that time it decreases and we see that the range of that force is considerably wide.

A finger-tip can perceive the magnitude of the force of deformation and the naked eye can make a clear distinction between perfect and imperfect returns. This may be the basis of the finger-tip method.

Fig. 3 illustrates an instrument[1] for practical use constructed on the basis of the finger-tip method. The construction of the instrument is shown in Fig. 4, A. In this instrument, the force needed for pressing a sphere on a fish as shown in Fig. 4, B is measured by a pressure gauge.

To see the function of our instrument, we made the following two experiments: (1) Reading of our instrument on fishes which have been stored during several days and (2) reading of our instrument on fishes on market, in relation to days after fishing.

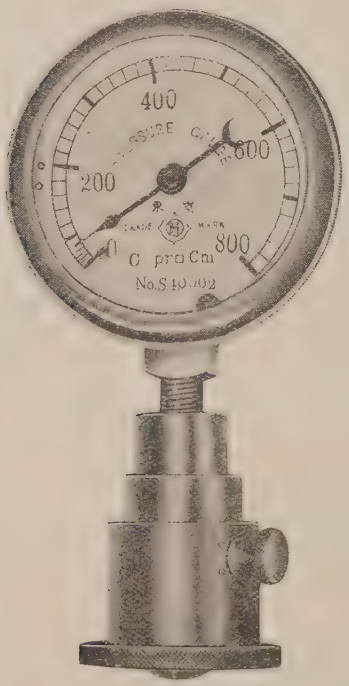

Fig. 3.

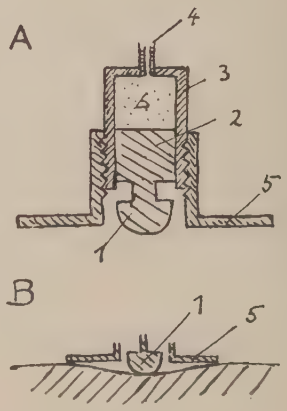

Fig. 4.

1, sphere; 2, piston; 3, cylinder; 4, connecting tube; 5, fixed ring; 6, oil chamber.

(1) This instrument is designed by Mr. Matutatô YOSIDA and it is constructed under his supervision.

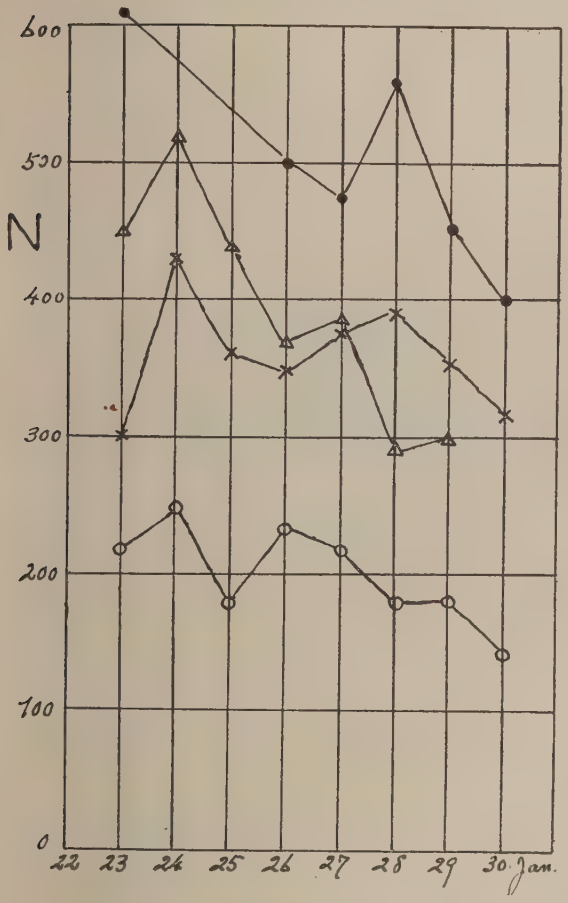

Fig. 5.

Change in the reading, N, during the storing.

● ..... *Tai.* ○ .....*Amadai.*
× ..... *Mezi.* △ .....*Hirame.*

Fishes used in the first experiment were angled in several places in the afternoon on 22nd Jan. '30 and dipped in the salt-water with ice during the transportation. At eleven o'clock in the morning on 23rd they were transferred in renewed salt-water with ice and at noon every day thereafter the reading was followed by renewal of the salt-water and ice was filled up. The temperature of the salt-water was kept at $+2°\sim-1°C$ during the experiment. Of course, the observation was limited in the portion above referred to and it was avoided to repeat the observation at the same position within a few days. Fig. 5 shows the result of the experiment. All the fishes used were in the state of rigor mortis on 23rd. Bad smell was emitted on 28th in *Tai*, and on 29th in *Amadai*, but it was not until 30th in *Hirame* and *Mezi*. On 30th, *Mezi* was able to be used without cooking while the other three by cooking.

The second experiment was done at a fish market in every early morn-

Table II.

Correlation table between the reading of our instrument and the days after fishing.

Tai

Reading \ Days	1	2	3	4	5
750–700	1				
700–650		1			
650–600	5				
600–550	8	5			
550–500	2	3			
500–450	2	9			
450–400	3	6			
400–350	9	4			
350–300	11			2	
300–250	15	5	1	5	1
250–200	4	10	6	11	4
200–150	1	6	5	1	2
150–100		1		1	
100–50					
50–0					
No. of individuals	61	50	12	20	7
Average value of the reading	390	365	210	240	220

Amadai

Reading \ Days	1	2	3	4	5	6
500–450	1	1				
450–400						
400–350						
350–300	1					
300–250	2	4				
250–200	8	5	3			
200–150	6	6	15	2		6
150–100	9	3	2	18		19
100–50	1	2		21		21
50–0						6
No. of individuals	28	21	20	41		52
Average value of the reading	195	205	180	105		100

Hirame

Reading \ Days	1	2	3	4	5	6
400–350	1					
350–300			1			
300–250	3	1				
250–200	9					
200–150	5	3	1			
150–100	1	2				7
100–50						5
50–0						3
No. of individuals	19	6	2			15
Average value of the reading	220	175	250			90

Mezi

Reading \ Days	1	2	3	4	5	6
600–550			1			
550–500	1					
500–450	1	3		2		1
450–400	2			1		
400–350	1	1	1			
350–300	4			1		
300–250				2		
250–200	3	4	2	3		1
200–150	3	2		7		7
150–100				3		3
100–50				1		1
50–0						
No. of individuals	15	10	4	20		12
Average value of the reading	315	305	350	230		160

ing from 21st Dec. '29 to 27th Jan. '30. The reading was taken on fishes just on the way from fishing boats to the depository of the market and at the same time the date of fishing of those fishes was told by the person in charge of fishes. Thus, as the observation was made in hasty condition, there was a notable difference in the size of fishes and in the position at which the reading was taken, and the date of fishing may be in some measure inaccurate. Table II gives the results obtained. Fig. 6 shows the average value of the reading in relation to the days after fishing.

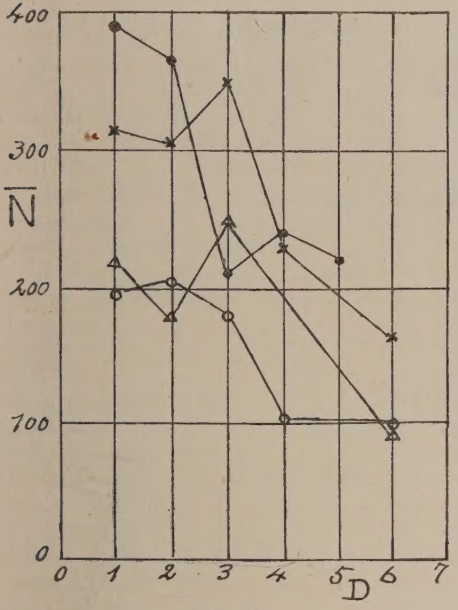

Fig. 6.

Relation between the average value of the reading of our instrument, $\bar{N}$ and the days after fishing, D.

● .....*Tai.* ○ .....*Amadai.*
× .....*Mezi.* △ .....*Hirame.*

The relations between the reading and the days shown in Figs. 5 and 6 do not well coincide with each other: That is, (a) the decreasing rate of the reading in Fig. 6 is much higher than that in Fig. 5; and (b) in the cases of *Tai* and *Hirame*, the reading is lower in Fig. 6 than in Fig. 5 when D=1. But the disagreements (a) is clearly due to the fact that the temperature of storing in the first experiment is lower than that during the transportation in the second, and the disagreement (b), due to that, in the case of *Tai*, many of individuals tested in the second experiments were much smaller than the fish used in the first and in the case of *Hirame*, the individuals in the second experiment were not handled with so careful treatment as the fish in the first experiment during the transportation. So, neglecting those disagreements, Figs. 5 and 6 can be conceived to show that our instrument is of fair service. The number of days after death can fairly be estimated from

the reading of our instrument, at least in the case where fishes are treated in same way and kept at the same temperature.

Fish decomposes by the action of enzymes and bacteria. And if the freshness of fish depends upon the stage of decomposition only and if the rate of decomposition is not affected by a mechanical action during the transportation, then the freshness seems to be judged by the chemical analysis of amino-acid and ammonia but not by the determination of the force of deformation. We will decide this question in near future.

Feb., 1931. Physical Laboratory, Imp. Fisher. Inst.

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